

Early mineralogy in Great Britain and Ireland

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Early natural histories and catalogues

Minerals, apart from their use as charms and as *materia medica*, had attracted little attention among scientifically-minded men in Britain before the last quarter of the seventeenth century. An early work published in Oxford in 1661 was Robert Lovell's *Panzoologico-mineralogia, or a compleat history of animals and minerals containing the summe of all authors both ancient and modern, galenical and chymical, touching earths, metalls, semi-metalls, with their natural and artificial excrements, salts, sulphurs and stones, more pretious and less pretious, etc.* The part dealing with minerals is chiefly devoted to their 'medicinal' uses with the sketchiest indications of where they are to be found. The list, under *Lithologia*, of 'stones or jewels more pretious' is quite extensive beginning with Achates, Amethyst, Berill, Bezoarstone and ending with Topaz; while the list of 'stones less pretious' runs from Alabaster to Unicorne-stone and Whetstone, and includes Load-stone of which Lovell's account is quoted by Miss Jessie M. Sweet (1935) in her description of Sir Hans Sloane's *Materia Medica*.

Another of the early works which were brought to my attention by Dr Roy Porter is Christopher Merret's *Pinax rerum naturalium Britannicorum continens vegetabilia, animalia, et fossilia in hac Insula reperta inchoatus*; published in London in 1666, with another edition in 1667. Here the author is more concerned with their uses and, to some extent, with localities where some of the 'fossils' are to be found. Thus he records that lead and manganese occur in the Mendip Hills, and under *Diaphani*, the first entry is 'Adamantes quos vocant Bristoll stones'. Irish slate (*Lapis Hibernicae*) is listed but its use is described, not as in Lovell, 'often used against bruises etc.', but for 'writing down things to be remembered'.

Another seventeenth century work, John Webster's *Metallographia: or an history of metals, etc.* 1671, treats of metals and their ores and mines with a chapter on 'other stones' including chrysollosa, Magnes, the Load-stone, Blood-stone, Schistum, the Lazul-stone, etc., and a final chapter on the transmutation of metals.

There is some mention of minerals in Robert Plot's *Natural history of Oxford-shire* (1677), and in his later work, *The natural history of Stafford-shire* (1686), both of which are referred to below, but of more particular interest, because of its detailed treatment of minerals, is the catalogue of the minerals (and fossils) in the Royal Society's Collections by Dr Nehemiah Grew

(1681). This collection was commenced very early in the history of the Royal Society, founded in 1660. Robert Hooke was appointed curator in 1662. His chief duty was to furnish the Society with experiments at their meetings, but he was himself very wishful to have 'as full and complete a collection of all varieties of Natural bodies as could be obtained'. The use of such a collection is 'for the most serious and diligent study of the most able proficient in natural philosophy' (Edwards, 1931 : 56).

The whole collection was transferred to the British Museum in 1781. Some of the fossils are still identifiable but none of the mineral specimens with any certainty. However, Grew's Catalogue shows something of the state of the knowledge of minerals as it was in England nearly three hundred years ago. The catalogue of the 'Minerals' is divided into three Sections: of Stones; of Metals; and of Mineral Principles and each Section is divided into chapters.

In Section I the first three chapters deal with fossils, as now understood, and then follow three more: of Gems; of Regular Stones; and of Irregular Stones.

The first entry under Gems is 'Diamonds' but whether the specimen really contained diamonds seems doubtful. Then come: Crystal, including Amethyst, both pale violet and white are mentioned; The Granate; Topaz, Smaragdus, Agate, Calcedony, Onyx, Sardonyx, Jaspis [a 'geometric jaspis', figured in pl. 20, appears to be chialstolite], the Nephritic Stone, and Turcois. They are briefly described and their medicinal properties are frequently mentioned.

Chapter V, of Regular Stones, deals with a great variety: here are some Stalagmitic Stones, Eagle Stones, Toadstones, Belemnites, a flint arrow head, and also various Spars. A 'Silver Spar' figured in plate 21, is a group of quartz crystals 'composed into the figure of a great bud of the colour of grey crystal'. Talk, and the 'foliated Talk' (figured in pl. 21), are gypsum, but 'a great crystalline Talk-spar' sent by Dr Erasmus Bartholinus is Iceland Spar 'dug out of a very high mountain in Island, one whole side of which consists of this Spar'. Another 'Spar' is 'a rhomb of Muscovy Glass. By most called Selenites, used in Saxony and other places in Germany in Windows'.

Grew also describes several kinds of Septarian nodules, which he names 'Waxen Veins'. One of these is the 'Starred Waxen Vein' that was given by Sir Rob. Moray (a founder member of the Royal Society) 'Found in the Isle of Sheppey'.

The starred waxen vein is a name for the radiating groups of crystals of baryte found on the septa of some of the septarian nodules 'waxen veins', from the Isle of Sheppey. Grew noted that 'This star is of quite different nature from the stone on which it grows, as making no effervescence with acids . . . '.

Another name for these radiating barytes was Astrapia. They were so described by the Rev. Dr John Walker, Jameson's predecessor as professor in Edinburgh. Jameson mentions having seen specimens so labelled in the Leverian Museum on his visit to London in 1793 (Sweet, 1963).

Chapter VI, of Irregular Stones, includes a great variety of minerals not exhibiting any regular form. So here are brought together: Emery; Flint; Serpentine Marble, called Ophites; Lapislazuli, i.e. 'blewstone'; 'Loadstone' from Magnesia 'a country between Thessaly and Macedonia'; Soapstone, Pumis Stone, and a 'cynder' from Etna.

Section II, of Metals, is treated in three 'Chapters': Of Gold, Silver and Copper; Of Tin, Lead and Iron; Of Antimony, Mercury and other Metallic bodies. In this last are found Cinnabar, Marchasite, Mundick, and Pyrites.

Section III, Of Mineral Principles, includes: Chapter I, Of Salts (Sal-ammoniac, Salt, Blue and Green Vitriol); Chapter II, Of Ambers and Sulphurs, under which head are also: Bitumens, and also 'Flake Stone Coal, by some called Black Amber', [Jet], 'found in Misnia, Bohemia'. Lastly, Chapter III, Of Earths, includes various Boles (Lemnian, Armenian, etc.) Volcanic Ash from Vesuvius, presented by J. Evelyn Esq., and 'earth which rained lately upon Teneriff' ['Blood Rain'; see Bannerman, 1922]. This Catalogue, then, gives an indication of the nomenclature and of some of the ideas in vogue with such persons, doctors and others, as had any knowledge of minerals in those days. The names and ideas were derived no doubt in part from Theophrastus, Pliny, Agricola, and Aldrovandi and, of seventeenth-century writers, Boetius de Boodt and John de Laet, to all of whom Grew refers.

At the very end of the seventeenth century there was published Edward Lhuyd's *Lithophylacii*

Britannici Ichnographia . . . (1699). It is chiefly of importance to palaeontologists but its first chapter is a catalogue of the mineral specimens in the collection at the Ashmolean Museum, made in part at least by Richard Dyer and labelled by Lhuyd who was Under-Keeper in 1684 and became Head-Keeper in 1690 (Gunther, 1945 : 222).

The entries are in Latin and the catalogue lists various specimens of quartz (*crystallus* and *iris*), including '*Iris vulgaris, Adamas Bristoliensium vulgo dicta*' (pl. I, fig. 15), a doubly terminated crystal of quartz; and a much larger crystal, from Snowdonia; '*Crystallus maxima Britannica, . . . Invenimus Alpibus Arvoniae juxta lacum Fynnon Vrech, . . .*'. There are also listed several varieties of 'Fluor' of which some called *Fluor triquetrus* appear from their figure (pl. I, fig. 34) to be dolomite or calcite. Other specimens are numerous Stalagmites, Selenites, and Talcum (gypsum). The collection contained ninety specimens.

References in the catalogue are made to Aldrovandi, Agricola, Dr Greb [i.e. Grew] and to Plot. The last mentioned reference is to Robert Plot's *Natural history of Oxford-shire* (1677 : 96), referred to above, in which he describes a few minerals encountered in the county. They include: 'Chrystals, Selenites, and Spars' of which some are 'by the Miners called *Cawke* and the Latins, *Fluores*; which (say they) yet retain so much fluid, that with the heat of fire, like *Ice* in the *Sun*, they melt and flow'.

In his later work, *The natural history of Stafford-shire* (1686), Plot wrote at length on the coal and iron-stone of the county. Of crystals he describes Selenites of several kinds of which one (pl. xi, fig. 1) is a cleavage rhomb of calcite 'of a cubico-rhomboidal form, all the pieces being constantly Hexaedra of equal obliquangular sides, or oblique angled Parallelpipeds'. He gives a good description of quartz crystals 'sometimes stained a violaceous colour . . . found in digging in Barrow-hill in Pesnet-Chase' (pl. xi, fig. 8); also of a group of scalenohedra of calcite 'from limestone rocks near Dudley'.

In addition to his notes on these minerals in the two county 'natural histories' Plot has two short papers in the *Philosophical Transactions*. One is on the sand in the brine of the salt works in Staffordshire (1683); the other, 'on Black-Lead, found only at Keswick and there called Wadt or Kellow' (Plot, 1699).

Two other county natural histories a little later than Plot's *Stafford-shire* are Charles Leigh's *Natural history of Lancashire, Cheshire, and the Peak in Derbyshire*, published in 1700, and the Reverend Thomas Robinson's *Essay towards a natural history of Westmorland and Cumberland*, published in 1709.

Leigh's work, illustrated with many plates of antiquities and some 'fossils', gives some account of numerous 'Spars of several sorts', Fluor in Derbyshire, Salt Rocks in Cheshire, Iron ores, Lead ores, Copper ores, Vitriol, Pyrites and Potters' Clay, and many others, listed in an extensive index.

Robinson's book gives some account of 'several mineral and surface productions' of the two counties but perhaps its interest is more theological than mineralogical, for to it is annexed 'A Vindication of the Philosophical and Theological paraphrase of the Mosaick system of Creation'.

There were some 'minerals, stones and earths' in the collection of Sir Hans Sloane, commenced probably about 1690, and also 'Pretious stones, agates, jaspers, etc.' and 'Vessels' of the same, probably from the still earlier collection of William Courten (or Charlton) which was bequeathed to Sloane in 1702; this collection contained over 10 000 items listed under Mineralogy in the synopsis prepared after Sloane's death in 1753. Such specimens from Sloane's collection as can be identified in the Department of Mineralogy of the British Museum (Natural History) have been recorded and described by Miss J. M. Sweet (1935), formerly of that Department, with illustrations of several of the bowls and rings in agate, mocha-stone, carnelian and jasper, and two beautiful pieces in jade (nephrite); a two-handled bowl and a carved mirror-frame.

Another collection of about the same period but devoted entirely to 'minerals and extraneous fossils' was started about 1696 by the remarkable Dr John Woodward, Professor of Physic in Gresham College in London. This collection was bequeathed to the University of Cambridge in 1728 together with a sum of money to found a Professorship, now the Woodwardian Professorship of Geology. The collection has been retained in its original arrangement, and with it is kept Woodward's own catalogue.

Most valuable to the study of this collection and its classification is a book, published in two parts in 1728 and 1729, after Woodward's death, which comprised *A catalogue of the English fossils in the collection of John Woodward* and lists also of the foreign minerals and fossils therein. Earlier, 1695, Woodward had produced *An essay toward a natural history of the Earth* and in 1696 a remarkable pamphlet which gave detailed instructions for making scientific observations and for 'Collecting, preserving, and sending over natural things', in fact instructions for collectors of geological, botanical and zoological material.

Something of the same kind with particular reference to mines and quarries appears in chapters of another book by Woodward published in 1728 entitled *Fossils of all kinds digested into a method*. The 'method' classifies the minerals into 1, Earths; 2, Stones; 3, Salts [Fossil salt; Salammoniac, and tincal (borax)]; 4, Bitumens [liquid naphtha, Barbadoes Tar]; 5, Minerals; and 6, Metals. The Earths are subdivided into (i) 'Those found in Strata'; and (ii) 'Those found in smaller masses', which are again subdivided, the first division being 'such as do not exceed marble in hardness'. These are 'Boulder stones, clay-stones and stony nodules'. Most of the semi-precious stones are referred to this division.

Dr V. A. Eyles in an article on John Woodward remarked that Woodward was the first British author to publish a work solely devoted to the classification of minerals (Eyles, 1965). A more nearly contemporary comment is made by Thomas Pennant who, in a letter to Edward Rawstone in 1753, wrote that he favoured Woodward's System and considered it now 'generally esteemed the most plausible' (Smith, 1913).

Another 'classification' not much noticed, perhaps in consequence of its truly remarkable nomenclature, is that of John Hill, the King's gardener at Kew, who published a general Natural History in three folio volumes (1748-1752), the first of which is devoted to 'The history of fossils'.

Emanuel Mendes da Costa (1717-1791), curator of the Royal Society's Collections, also attempted *A natural history of fossils* but only the preface and the first volume was published owing, da Costa implies, to lack of sufficiently numerous subscribers. The published volume (1757) deals only with Earths and Stones: Marbles, *Marmora profera* (basalts, etc.) and Granites. It is chiefly notable for its description (with a plate) of the Giant's Causeway, quoting observations by Dr Richard Pococke, Bishop of Ossory, and Mrs Susannah Drury.

John Morton, who published *A natural history of Northamptonshire* in 1712, treats of minerals on somewhat similar lines to Woodward; Chapter I dealing with Earths, including the Earths of the Lower Strata; Chapter II with Stones; and, Chapter II, part 2, with 'Stones in lesser masses'. Here are included Pyritae, Sparry Nodules, Belemnites, Bezoar, Aetites (Eagle Stones), Geodes, and Enhydros, and Selenitae. He remarks that 'Selenitae, found at Worthrop [WORTHROP = Wothorpe 1 mile west of Stamford-Baron, Northants] in the lane leading to Stamford are there called 'Worthrop diamonds'. With an eye to possible economic uses for the minerals in the county he opines that Selenitae are composed of the same matter as Talc ['Laminated gypsum' was sometimes called 'Talc'; see p. 4] and 'we may fully make use (in medicine) of the Selenitae our County affords in plenty instead of the Talc of Italy and other foreign countries'. He also suggests that if the silver-coloured 'pyritae, which are generally stored with vitriol particularly of the copperas kind, are found in sufficient plenty a copperas work for making of ink might be set up in the County' (Morton, 1712).

Another county natural history and one which deals mainly with rocks, minerals and mining is *The natural history of Cornwall* by William Borlase, Rector of Ludgvan, published in 1758. Here again are chapters on Earths, Clays, Steatites or Soapstones, and then: Stones of use, Stones of ornament and curiosity, and Stones of profit. Spars and crystals of various kinds are described and there are plates of several. Borlase distinguished between crystals plain (i.e. massive), incrustations, stalactitic forms, etc., and figured crystals (i.e. showing crystal form). Stones of profit are the products of the mines. Here are described: Bismuth, speltre, naphtha, antimony, manganese, loadstone, molybdaena, cobalt, and Mundic, . . . a long account of this last. Chapters on metals deal with: tin, iron, copper, silver, lead and quicksilver, and gold, as they occurred in Cornwall. Borlase had made a considerable collection of antiquities, fossils, and minerals, which, during his lifetime, he had given to the (old) Ashmolean Museum. It seems that none of them has survived (Gunther, 1925 : 223).

Eighteenth-century and nineteenth-century mineral collections

Here may be mentioned also several other mineral collections made in the eighteenth century, and the early part of the nineteenth, by various gentlemen in Cornwall, some of whom were adventurers in the Cornish mines, and with them I shall mention also Thomas Pennant, zoologist and author, of Whiteford in Holywell, Flintshire, who, while an undergraduate at Oxford, visited Borlase in Cornwall in 1746 or 1747, and started to make a collection of minerals from that time.

Most of our knowledge of these early collections we owe to Sir Arthur Russell, who in the course of time incorporated parts of the Cornish ones into his own collection which with his manuscript notes he bequeathed to the British Museum (Natural History) (Kingsbury, 1966).

These collections were being made at a time when splendid specimens were obtainable from the higher levels of the mines of Cornwall and Devon. One of the earliest was that of Philip Rashleigh of Menabilly (1729–1811), to which I shall refer again. Others, slightly later, were the collections made by John Hawkins of Trewithen (1761–1841), Edmund Pearce (1788–1856), and the three members of the Fox family of Falmouth: George (1784–1850), Robert Were Fox (1789–1877) and Alfred (1794–1874). Still others were those of John Williams of Scorrier (1753–1841), Sir John St Aubyn (1758–1839), and Joseph Carne of Penzance (1781–1858).

John Williams of Scorrier was principal agent for the North Down and Gwennap mines. Charles Hatchett visited him in 1796 and records in his diary that at that time Scorrier was said by C. S. Gilbert to 'contain the most valuable variety of mineral specimens of any house in Europe' (Raistrick, 1967). The collection was added to by John Williams' son, John Michael (1813–1880) and by his grandson, John Charles of Caerhays Castle (1851–1939), who in 1893 presented 550 selected specimens to the British Museum (Natural History). In 1948 a further selection of 585 specimens was purchased by Sir Arthur Russell.

The St Aubyn Collection, one of the many catalogued by Bournon (see below), was in 1876, according to Sir Arthur Church, in the Town Hall at Devonport and it was then accompanied by Bournon's catalogue (Church, 1877). All that now remains of it is in the Plymouth City Museum, where it is being carefully curated by the Keeper of Natural History. Two of the original volumes of Bournon's catalogue have been saved, though both Plymouth and Devonport suffered severely from bombing in the 1939–1945 war: xerographic copies are in the Mineralogy Library, British Museum (Natural History).

The Carne Collection now forms part of the mineral collection of the Department of Mineralogy and Petrology at Cambridge. Also in the same collection is that made by Sir Abraham Hume (1749–1838) which, together with his collection of diamonds (see p. 59), was presented to the University by Viscount Alford in 1841. The Mineral Collection in the British Museum which, up to the end of the eighteenth century, consisted almost entirely of the minerals from Sir Hans Sloane's collection, received three notable additions in the period 1799–1810. A collection containing many choice specimens formed by the Rev. Clayton Mordaunt Cracherode (1730–1799) was bequeathed to the British Museum in 1799. In that same year the Museum purchased the large collection of minerals and rocks formed by Charles Hatchett and which included a fine set of Russian minerals. A much larger addition was made in 1810 when the collection of Charles Francis Greville (1749–1809), said to contain 20 000 specimens, was purchased for the nation by a special vote of £13 727. By that time Charles Konig had been appointed an assistant in the Natural History Department and had been given charge of the Mineral Collection and its arrangement (Smith, 1969)¹.

The Rashleigh Collection, which, as mentioned above, was the earliest of the Cornish collections of this period, is important not only because it contained splendid specimens from Cornwall and from other parts of Britain and from abroad, but also because it was carefully catalogued by Rashleigh himself. The main part of this collection was acquired by the Royal Institution of

¹ There was also in the Royal Institution founded by Count Rumford in 1799 'a museum of more than 3,000 mineral specimens and fossils, including a special collection of minerals, presented by Sir Humphry Davy' (Woodward, 1907 : 9). This may have been incorporated in the collections of the Geological Museum, Institute of Geological Sciences.

Cornwall and is in the County Museum and Art Gallery in Truro. The original catalogue, and also a later one compiled by Arthur Aikin in 1814, are preserved with the collection; a xerograph copy of Rashleigh's original catalogue is in the Department of Mineralogy at the British Museum (Natural History). Another part of the original collection, given during his lifetime by Rashleigh to his son Jonathan, was lost sight of until 1923 when it was traced and purchased by Sir Arthur Russell. The original catalogue contained entries for 3902 specimens. It followed a simple classification into 'ores of various metals, followed by the principal non-metallic species' (Russell, 1952a).

Philip Rashleigh himself published in two parts, in 1797 and 1802, a beautifully illustrated book entitled *Specimens of British minerals selected from the cabinet of Philip Rashleigh*.

Another collection, important also because it was accompanied by a contemporary catalogue, is that of Thomas Pennant (1726–1798). The collection did not contain many specimens remarkable for their beauty such as were found in Rashleigh's collection but it was rich in minerals from the mines of Pennant's home county, Flintshire. It had remained in its original cabinets for over a century since his death. The catalogue, in two volumes, by Pennant himself was started about 1757 and contains some 1250 entries. As mentioned above (p. 52) the classification 'favoured Woodward's System'. It is set out in full in a short account of Thomas Pennant written in 1913, the year in which the Earl of Denbigh presented the collection to the British Museum (Natural History) (Smith, 1913).

Crystal form did not enter into Pennant's classification though he did divide the Spars into: 'crystalliform or cubic' and 'Spars breaking into rhomboid or parallelopiped masses'. However, calcite specimens are found entered under both divisions and it is evident from an entry under *spatum Islandicum*, from Pen-y-Bryn mine, that he did not distinguish between cubic and rhombohedral cleavage. It is, however, perhaps only fair to remark that this was sixteen years before Torbern Bergman wrote his celebrated paper (1773) 'Variae crystallorum formae, a spatho ortae, explicatae', in which he demonstrated that prisms and scalenohedra of calcite could be built up from cleavage rhombohedra suitably arranged.

Other important collections made in the nineteenth century

The collecting of fine mineral specimens continued to be fashionable throughout the first half of the nineteenth century and was greatly stimulated by a celebrated mineral dealer, Henry Heuland. Sir Arthur Russell has given an interesting account of him (Russell, 1952b) and, more recently, Frondel (1972) and Whitehead (1973) have written about Heuland's uncle, Jacob Forster.

Forster's collection, with additional material supplied by Heuland, was sold in 1820 to C. H. Turner. Heuland employed Armand Lévy to compile an illustrated catalogue of the collection. Lévy began, but failed to complete it and the catalogue was finished by H. E. Brookes and published in three quarto volumes in 1838. This collection, and another made by William Nevill, was acquired by Henry Ludlam to add to his own already fine collection. The whole was bequeathed to the Museum of Practical Geology. At the time of Ludlam's early death in 1880 it was regarded as 'the most complete and probably the finest collection of minerals ever made by a private collector' (Davies, 1881).

A fine collection made by Lady Louisa Aylesford (1761–1832) was bought by Heuland, and specimens from it along with others from Heuland's own collection were auctioned at Heuland's sales between 1833 and 1839. Many were bought by the British Museum.

Another collection in which most of the specimens were bought at Heuland's sales between 1826 and 1847 was made by Isaac Walker (1793–1853) of Arnos Grove, Southgate, London, and added to, perhaps by his sons. It was purchased in 1912 by S. Henson, mineral dealer of London. Many of the finest specimens were acquired by the Department of Mineralogy, British Museum (Natural History), a considerable number being presented by F. N. Ashcroft (Anon., [Spencer], 1913a).

In Edinburgh Thomas Allan (see p. 60) was making a notable collection. He collected minerals in England, Ireland, and the Faroe Islands, as well as in Scotland. He had bought Giesecke's first Greenland collection (see p. 57), and Haidinger had travelled in Europe with young Robert

Allan (see p. 61) in about 1825 to procure more specimens. The whole collection was purchased in 1835 for £1300 by Robert Hyde Greg. It was added to later by his son R. P. Greg who, with W. G. Lettsom, was co-author of the *Manual of the mineralogy of Great Britain and Ireland* (1858). This collection, known as the Allan–Greg Collection, was acquired by the Department of Mineralogy of the British Museum in 1860. It was one of the earliest and perhaps the most important purchase arranged by Story-Maskelyne in his early years as Keeper of Minerals (see below, p. 68).

A large collection of minerals was made by Robert Jameson during the long period during which he was Regius Professor of Natural History in Edinburgh and it formed the main part of the general collection of minerals in the Royal Scottish Museum. It incorporated the still earlier collection made by Dr John Walker. He had published two editions of a classification of ‘fossils’ for use in the University (Sweet, 1963).

Elsewhere in Scotland, about the middle of the century, M. F. Heddle, then newly returned from studying at Clausthal and Freiberg, was adding to his earlier collection of Scottish minerals, collecting much material from the islands as well as from the mainland. After 1850 he was often accompanied by his friend Patrick Dudgeon of Cargen, who had himself built up a fine collection of minerals which he gave to the nation in 1890 (Heddle, 1897). Heddle’s Collection was also acquired by the Edinburgh Museum of Science and Art, now the Royal Scottish Museum, partly by purchase and partly by gift. It was arranged by Heddle himself a year or so before his death in 1897 (Goodchild, 1900).

Another collection of minerals, probably chosen mainly for their aesthetic appeal, was made by John Ruskin who as a student at Oxford had attended Buckland’s lectures on geology and mineralogy in 1837. His published diaries show that in 1866 and 1868 he was buying specimens from such well-known dealers as Bryce Wright, Tennant, and Talling of Lostwithiel, and that at that time he was living at Denmark Hill in South London. He retired to Brantwood on Lake Coniston, in the English Lake District, in 1884 and at about that time he presented specimens to the British Museum (Natural History), St David’s School, Reigate, and the Kirkcudbright Museum, each collection being provided with a catalogue. Other specimens were presented to the St George’s Guild and to the Museum of Science and Art at Sheffield. Many specimens once belonging to Ruskin came to the Mineral Collection in the University Museum at Oxford when the collection of Mr George Allen of Orpington, Kent, was purchased in 1908. The main part of the collection that remained at Brantwood was bought by Sir Arthur Russell in 1931.

In north-east England there were many collections of minerals, some rich in the minerals of the mines of Yorkshire and Durham. I have no personal knowledge of these collections except that made by C. O. Trechmann (1851–1917) part of which, including many specimens of the sulpharsenites of the Binnenthal, was bequeathed to the British Museum (Natural History) in 1917, and a greater part presented by his son C. T. Trechmann in 1926.

At Chatsworth there was a collection of specimens from the mines owned by the Dukes of Devonshire which included some fine and large specimens.

William Phillips’ mineral collection (see p. 65) which was sold by private treaty at Sotheby’s in London in 1829 was purchased by Dr Rutter of Liverpool. He presented it to the Medical Institution of Liverpool and eventually it was transferred to the Liverpool Museum. It consisted of small, mostly well-crystallized specimens. Many of the crystals had been measured by Phillips and the results published in his books. It was destroyed by bombing in May 1941.

There was also a mineral collection at Alnwick Castle made by the Duchess of Northumberland, Lady Charlotte Patricia Clive, who married the 3rd Duke in 1817. This was part of a larger collection of natural history specimens and ‘Curiosities’ sold by auction at Sotheby’s on 9 July 1968. Among the specimens were ores from Alston Moor, fluorite from Allenheads, malachite and beryl from Siberia, rock crystal, axinite from Dauphiné, calcite from Andreasberg, and two gold nuggets from Co. Wicklow.

A collection of minerals and fossils was located at Wallington Hall, one of the homes of Sir Walter C. Trevelyan (1797–1879), primarily a botanist but also an active geologist. He presented many specimens to the Museum of the Natural History Society of Northumberland, Durham, and Newcastle upon Tyne, now the Hancock Museum, in Newcastle upon Tyne.

For notes on other collections in the Hancock Museum I am greatly indebted to Miss Susan Turner of that Museum. A very early collection, containing some minerals, is the Cookson Collection which seems to have been in existence at least since 1743. Some fine specimens were presented by Thomas Sopwith (1803–1879), manager of Beaumont's mines in Allendale from 1845 to 1871. More important, however, is the collection formed by William Hutton (1798–1860) which was on loan to the Hancock Museum from 1831. After Hutton's death it was purchased from the executors by Sir William Armstrong and presented by him to the Museum in 1880. It is rich in minerals from the north of England, including well-known localities in Weardale, Alston, and Carrock Fell. It was owing to Hutton's efforts that 'a splendid collection of minerals and geological specimens illustrative of the mineral productions of the Russian Empire made by the command of His Imperial Majesty, Tsar Nicholas I, and presented by him to the Society [The Natural History Society of Northumberland, Durham, and Newcastle upon Tyne]' was secured for the Museum on 15 October 1838. This collection was catalogued by the late Dr S. I. Tomkeieff in 1935.

Early mineral analysts

By the end of the eighteenth century some chemists in England were becoming interested in the analysis of mineral substances. Such was William Gregor, a Cornishman, born in 1761, a graduate of St John's College, Cambridge, and for many years Vicar of Creed, near Grampound, Cornwall. As a result of his analyses of menaccanite from a stream-bed at Menaccan he discovered a new metal, later re-discovered by Klaproth and by him named titanium (Russell, 1955).

Other chemists in London, chiefly interested in the analysis of mineral substances, formed, in 1799, the British Mineralogical Society, in a sense the predecessor of the present Mineralogical Society. The Minute Book of the Society is in the Mineralogy Library, British Museum (Natural History). An account of its brief existence (1799–1806) is given by Professor W. W. Watts in his address on the occasion of the Jubilee meeting of the Mineralogical Society (Watts, 1926: 108–109). Among the members of this earlier Society was Charles Hatchett who had sold his collection of minerals to the British Museum in 1799 (see p. 53). Three years previously he had made a remarkable journey through England and Scotland visiting mines, smelting works and foundries and recording his observations (Raistrick, 1967). Hatchett was the discoverer of columbium (1802a); the story of this discovery has been told by Miss J. M. Sweet (1935), whose account of the Sloane minerals has been referred to above (p. 51).

Hatchett published numerous analyses of minerals between 1797 and 1804, the first, read before the Linnean Society, being 'On bituminous substances . . .' (Hatchett, 1798). His papers on columbite and columbium appeared later (Hatchett, 1802a, b). Unfortunately he seems to have given up chemical analysis a few years after this.

While members of the British Mineralogical Society were active in London there was working in Scotland, and for a time also in London, a chemist and mineralogist, Thomas Thomson (1773–1852). In his younger days he was a friend of John Dalton and of Wollaston and is credited with some share with them through his work on oxalic acid and certain oxalates, in the establishment of the Law of Multiple Proportions (Thomson, 1808a, b). He also published a *System of chemistry* in 1802 and lectured on chemistry in Edinburgh; in 1807 he opened a laboratory for practical instruction. He was editor of *Annals of Philosophy* from 1813 to 1820, went to Glasgow as a lecturer in 1817 and was appointed the first Professor of Chemistry there in 1818.

In 1836 he published *Outlines of mineralogy, geology and mineral analysis* in two volumes. The first volume, on mineralogy, is noticed later. Part 3, dealing with the methods of analysing minerals, has an introduction giving a history of mineral analysis and of the methods and recent improvements by European chemists including Berzelius and his pupils, Gmelin, Klaproth and H. Rose. Of British contributions he wrote: 'If we except Mr Hatchett and Mr Chenevix, Great Britain has produced very few analytical chemists. Almost the only modern chemists . . . who have published analyses of minerals are Mr R. Phillips, Dr Turner and Mr Connell.' Among Thomson's numerous mineral analyses are those of a native carbonate of strontium from Strontian (1816), of emmonite, a variety of strontianite from Massachusetts, and of holmite

(=seybertite), a brittle mica. He wrote also more general papers giving mineralogical observations on Cornwall (1814) and on minerals from the neighbourhood of Glasgow (1840), and in a paper on 'The needlestone from Kilpatrick in Dumbartonshire' (1820), he presented an extensive study of various zeolites: natrolite, scolecite, mesolite, and thomsonite, the last named for him by H. J. Brooke.

Between 1811 and 1816 he published in the *Memoirs of the Edinburgh Wernerian Society* three analyses of minerals from Greenland: sodalite, allanite, and magnetic iron-ore. Sodalite and allanite were new minerals, the latter named in honour of Thomas Allan of Edinburgh.

The history of these specimens is sufficiently interesting to allow a digression from the subject of early mineral analysts. A Danish ship, on its way from Iceland to Copenhagen, was captured by a French privateer, retaken by a British frigate and brought to Leith harbour. In the cargo was a collection of minerals which was sold by auction and bought for £40 by Thomas Allan, an Edinburgh banker, and Colonel Imrie. All that was known about the collection was that it had been shipped by a missionary from a harbour on Davis Straits. Allan concluded from the abundance of specimens of cryolite in the collection that it had come from Greenland and it subsequently transpired that it had been made by Karl Ludwig Metzler (afterwards Giesecke) during a six years' residence in Greenland. In 1813 Giesecke returned with another collection and visited Allan in Edinburgh. Soon after this, perhaps helped by Allan, he was appointed Professor of Mineralogy to the Royal Dublin Society (Sweet, 1967, 1974; Greenough, 1838).

Another Scottish chemist, who made many contributions to the analysis of minerals, was James Finlay Weir Johnston, born in Paisley in 1796. He had studied at Glasgow University, and was a pupil of Berzelius in 1812. In 1833 he became the first Reader in Chemistry and Mineralogy in the University of Durham, and was also Chemist to the Agricultural Society of Scotland. Among his numerous papers are two on minerals named by him: plumbocalcite (Johnston, 1832), and barytocalcite (=alstonite) and its dimorphism (Johnston, 1835). He reported the discovery of vanadium in Scotland and a vanadate of lead (1831), and described various hydrocarbons and mineral resins among which middletonite (1838a), गयाquilite (1838b) (the present spelling is guayaquilite), and pigotite (1840) were named by him as new.

Blow-pipe analysis seems to have been well developed in Britain for the determination of minerals. Edward Daniel Clarke, the first Professor of Mineralogy at Cambridge, became an internationally recognized authority on the 'gas blow-pipe', and J. G. Children, in 1822 an 'Assistant Librarian' in the Natural History Department of the British Museum, translated, through the French translation by Fresnel, a book on the use of the blow-pipe by J. J. Berzelius which had been published in 1820 (Children, 1822). In the *Elementary introduction to . . . mineralogy*, third edition, 1823, by William Phillips, there is a description of the methods of blow-pipe analysis as applied to minerals complete with details for beginners on how to 'blow' so as to produce 'from the flame of a common candle, a steady stream of flame': quite a difficult accomplishment.

Richard Kirwan F.R.S. (1733–1812), studied chemistry for some time in London but settled in Dublin in 1789 and became President of the Dublin Society (Sweet, 1967 : 122). In the second edition of his *Elements of mineralogy*, 1794–1796, whilst tracing the growth of mineralogy as a science, he refers to the debt the science owed in the decade 1774–1784 to Scheele and to Bergman, and in the subsequent period to Klaproth and to Werner. Had he been writing a little later he would surely have added 'and to Berzelius' for, far more important than Berzelius' work on blow-pipe analysis, just referred to, were the great improvements he introduced in the methods of gravimetric analysis. The high standards obtained by him must have given to mineralogists in this country a great incentive to achieve better analyses themselves.

We know of at least two early links with Berzelius, both from Scotland. One was J. F. W. Johnston, already mentioned, who was a pupil of Berzelius in 1812; the other a Scottish physician, William MacMichael, 'who worked in Berzelius' laboratory learning analytical procedures' in the winter of 1812/1813 (or 1813/1814). It is recorded that he stimulated his host's interest in mineralogy by giving him a collection of minerals he had bought, after he had selected those he wanted for the British Museum; and with reference to this incident Berzelius noted 'I accepted his friendly gift. Some time later, in order to arrange my collection, I began to study mineralogy.'

The further progress and improvements in the chemical analysis of minerals has recently been very well reviewed by Dr M. H. Hey in his Hallimond lecture to the Mineralogical Society (Hey, 1973), and though more is said later on British contributions to the chemistry and to classification based mainly on chemical composition one must give some account at this point of the influence of A. G. Werner on British mineralogists about the turn of the century.

The influence of Werner on the classification of minerals

Abraham Gottlob Werner had been appointed Inspector of Mining and Instructor in Mineralogy at the Mining Academy in Freiberg in 1775, at the age of 25. His great reputation as a teacher is always associated by geologists with the Neptunian or Plutonist controversy around which so many heated arguments arose in the early part of the nineteenth century, and in which both Richard Kirwan and Robert Jameson took very active parts. However, this discussion concerned mainly 'geognosy' and what is now called 'petrology', and Werner's great contribution to mineralogy is his first book: *Von den äusserlichen Kennzeichen der Fossilien*, published in 1774, of which a new translation by A. V. Carozzi has recently appeared (Werner [1962]).

The controversy which raged in Edinburgh between supporters of Werner and those of James Hutton indirectly did a considerable service to mineralogy and petrology, for it inspired Sir James Hall, a friend of Hutton's in Edinburgh, to make experiments on the fusibility of certain lavas, basalts, and dolerites, by which he demonstrated that on being cooled very slowly the fused products solidified not wholly as glass but were partly crystallized and stony (Hall, 1805). Later under extremely difficult experimental conditions he studied the effect of heating powdered limestone and chalk to high temperatures under pressure and showed that they could be melted under these conditions without dissociating (Hall, 1812). Thus, as Sir John Flett pointed out, he became the founder of experimental petrology although very many years were to elapse before his work was followed up with the much better facilities available in modern laboratories (Flett, 1922; see also Eyles, 1963; and Sweet & Waterston, 1967).

Hall began his experiments about 1790 but, apart from a paper read to the Royal Society of Edinburgh in that year, he refrained from publishing his results in full until after Hutton's death in 1797. In the meantime his experiments on the fusion of basalt had been repeated by Gregory Watt, using Cleve Hill dolerite in very large quantities, one or two hundredweight at a time (Watt, 1804).

To return to Werner's first book *On the external characters of minerals*: this has been described as a manual of determinative mineralogy, utilizing the external characteristics, colour, form, lustre, streak, hardness, and specific gravity (Eyles, 1964). Werner's method of identifying minerals could be studied by means of collections of specimens selected to illustrate the 'characteristics' relied on to distinguish one mineral from another. Such was the first of the five 'Collections' comprising the Leskean Collection formed by N. G. Leske, a Professor of Natural History in Leipzig in 1775, and a friend of Werner's from their student days.

One of the earliest personal contacts made with Werner by any mineralogist in the British Isles seems to have been by Richard Kirwan (see p. 57) who visited him in Freiberg and through him was able, in 1792, to arrange for the purchase by the Royal Dublin Society of the Leskean Collection. Kirwan intended this collection to be used in the teaching of mineralogy at the Mining Academy which it was proposed to form in Dublin. George Mitchell, a native of Belfast, and a student and graduate of the University of Dublin, worked there on the Leskean Collection and translated Karsten's catalogue of it in 1798.

In the previous year Robert Jameson visited Dublin and spent eight days carefully examining the Leskean Cabinet with Kirwan and Mitchell. He found some of the colour differences too minute; also among the different kinds of 'fractures' he 'found some beautiful distinctions but in many instances run into by few too great minuteness' [*sic*] (Sweet, 1967).

It was probably Jameson's meetings and discussions with Kirwan and Mitchell that encouraged him to enrol in 1800 as a student at Freiberg, where George Mitchell had also matriculated in 1798. Mitchell became one of Werner's favourite and most promising pupils. Unfortunately he died in 1803, and the Dublin Mining Academy was never established.

A year or two after his return from Freiberg, Robert Jameson was appointed Professor of Natural History in the University of Edinburgh. He had already published *An outline of the mineralogy of the Shetland Islands, and of the island of Arran* (1798); and also *Mineralogy of the Scottish Isles* in two volumes (1800). Both of these were written before his Freiberg visit, but his more important, three-volume *System of mineralogy* (1804) belongs to his 'Wernerian' period. In the preface to this work, he reviews the classifications of Cronstedt and Wallerius and introduces Werner's classification which he then adopts. In the following year he published *A treatise on the external characters of minerals*.

In Glasgow there was another supporter of Werner's system, the chemist Thomas Thomson, mentioned above (p. 56). He was a Vice-President of Jameson's Wernerian Natural History Society, and in the first volume of his *Annals of philosophy* (1813) he published a lengthy and somewhat violent attack on Richard Chenevix who, writing in Paris in the *Annales de chimie* in 1808, had criticized Werner's system of mineral classification and extolled that of Haüy.

Richard Kirwan published the first edition of his *Elements of mineralogy* in London in 1784, before his meetings with Werner. In this he follows the system of Cronstedt, 'founded almost entirely on chemical characters' as being 'received by all Europe', but he refers also to 'classification by external characters of which some able patrons have appeared of late among whom I shall mention only Werner and Mr Romé de Lisle'. In his second edition, however, he follows Werner's method.

Neither in Cambridge nor in Oxford were there active enthusiasts for Werner's methods. E. D. Clarke, the first Professor of Mineralogy in Cambridge, had learnt some crystallography from Haüy in Paris and probably left the classification of rocks to the Woodwardian Professor. However, I am indebted to Dr Roy Porter for pointing out that John Hailstone, Woodwardian Professor at Cambridge before Sedgwick, had studied at Freiberg and that his *Plan of a course of lectures in mineralogy* (1792) is highly Wernerian in tone and emphasis. It appears, however, that 'although he gave demonstrations to residents and strangers who visited the Woodwardian Museum, he never gave a single lecture' (Woodward, 1907 : 54). Meanwhile, in Oxford, John Kidd, the Professor of Chemistry, had carried on the teaching of mineralogy and geology begun by Sir Christopher Pegge, Professor of Physic. Kidd's teaching was given in a subterranean classroom under the Ashmolean Museum where 'nearly all the scientific teaching at Oxford had been accomplished since the days of Robert Plot' (Gunther, 1925 : 266). Kidd, in his *Outlines of mineralogy*, which he published in 1809, while acknowledging his indebtedness to Haüy, Brongniart, and Kirwan, followed a classification of his own. Kidd's famous successor, William Buckland, had he entered into the Wernerian controversy, would have been a 'plutonist'.

Systems of mineralogy and text-books

In London mineralogists, many of them members of the British Mineralogical Society (see p. 56), seem to have been interested chiefly in the minerals themselves, their chemistry, and crystal form. They had contacts with Europe, particularly with France, in spite of the wars, and they were hearing of the publications of Romé de l'Isle and the newer writings and teaching of the Abbé Haüy in Paris (Haüy, 1822). Haüy was able to send to Sir Joseph Banks in 1809 three copies of his *Tableau comparatif des résultats de la cristallographie et de l'analyse chimique relativement à la classification de minéraux*. One copy was for Greville, one for Bournon, and the third for Banks himself. This copy Banks put at the disposal of his geologist friends in his library. It is now in the library of the Department of Mineralogy in the British Museum (Natural History) (de Beer, 1960 : 184).

The rapid increase in interest among London mineralogists in minerals and crystals was partly, and perhaps mainly, due to the arrival in 1794 of a French royalist refugee Jacques Louis, Comte de Bournon, a pupil of Romé de l'Isle. He was soon employed 'curating' the mineral collections of Sir John St Aubyn, Sir Abraham Hume, of whose diamond collection he published a catalogue in 1815 (see p. 53), and the great collection of the Rt Hon. Charles Francis Greville (Woodward, 1907). Also he gave lectures in London, where he became associated with the leading mineralogists. Among these was William Babington, a busy London doctor, who arranged meetings of his

mineralogical friends at seven in the morning to fit them in before his patients claimed his attention (Whewell, 1842 : 65).

From these friends Babington raised a fund for the publication of Bournon's monograph on the crystal forms of carbonate of lime (Bournon, 1808). The original sponsors with Babington were William Allen and William and Richard Philips, and the other subscribers were: Sir John St Aubyn, Robert Ferguson, G. B. Greenough, Charles Francis Greville, Charles Hatchett, Luke Howard, Sir Abraham Hume, Richard Knight, Richard Laird, and John Williams, Jr. There were also Dr Crichton, Physician to the Emperor of Russia, and three other Russian patrons of science (Greenough, 1838 : 42).

Bournon had also been engaged by E. W. Gray, head of the Natural History Departments in the British Museum, to give help in selecting specimens from the Collection of Minerals for preservation, for duplicates, or for rejects, and in working on the catalogue. This engagement seems to have ended with the death of Gray in 1806.

When the Greville Collection of minerals was purchased in 1810 (see p. 53) Bournon hoped he would be put in charge of its removal from Greville's house to the British Museum. In the event the removal was done by the recently appointed 'assistant librarian', Charles Konig. Bournon complained that his 'tickets' were displaced, and certainly the only relic we have of Bournon's twelve years' work for Greville is a set of crystal models in wood accompanied by labels in Bournon's handwriting.

Perhaps it was the growing popularity of minerals among amateur collectors and students of the work of Romé de l'Isle and of Haüy that induced James Sowerby (1757–1822), first of a long line of naturalists, to produce his *British mineralogy*, with 550 plates in colour and descriptions of the specimens illustrated. This work ran to five volumes, the first appearing in 1804 and the last in 1817. He also published in 27 numbers *Exotic mineralogy* . . . , as a supplement to *British mineralogy* (Sowerby, 1811–1817 [1820]). The plates in *British mineralogy* were not arranged in any systematic order but there was a systematic index with each volume and this was completely revised in volume 5 and a separate, systematic *Catalogue of British minerals* was published in 1819 as a kind of appendix, to be used in making out labels for specimens in mineral collections (Sowerby, 1819).

Others attempted similar 'systems' to help collectors in the baffling task of arranging their specimens. William Babington had published *A systematic arrangement of minerals* in 1795, and an enlarged edition in 1799. This is described on the title page as being 'in the form of a catalogue after the manner of Baron Born's systematic catalogue of the collection of fossils of Mlle Eléonore de Raab'. The first edition seems to have been written when the author was arranging the mineral collection of the Earl of Bute; according to Greenough, Babington had purchased the Earl of Bute's collection, 'the finest, perhaps, which at that time existed in England' (Greenough, 1838 : 5). This collection passed into the possession of Sir John St Aubyn to whom the second edition of Babington's work was dedicated (see p. 53).

Arthur Aikin had also attempted a system, under which minerals could be arranged, in his *Manual of mineralogy* in 1814; this book included the substance of lectures given in the winter of 1813–1814 to some members of the Geological Society. He had been President of the British Mineralogical Society, and was Secretary of the Geological Society from 1812 to 1819. Aikin gave a general synopsis setting out a classification under which the minerals are described and chemical analyses quoted. The introduction discussed the characters of minerals and the means of testing them, with instructions on the use of the blow-pipe.

Thomas Allan in Edinburgh had published in 1808 *An alphabetical list of the names of minerals . . . with tables of analyses* and another edition in quarto in 1819 giving more space to the columns showing chemical composition. The names were listed in groups of: Saline minerals, Earthy minerals, Inflammables (Amber, Bitumen, Coal, etc.), and Metallic minerals. Synonyms were cross-indexed.

Another systematic mineralogy following to some extent the system of Werner was *The characteristic of the natural history system of mineralogy* by Friedrich Mohs. He was one of Werner's most successful students and succeeded him as professor in the Mining Academy of Freiberg. An English translation of this work was published in Edinburgh (Mohs, 1820a, b).

Lastly, one may mention the system of Berzelius 'based on his electro-chemical theory and the

doctrine of definite proportions' (Berzelius, 1814). This was published first in 1814 but was later (1824) modified as a result of Mitscherlich's discovery of isomorphism. This modified system 'with occasional slight deviations' was adopted by Konig for the rearrangement of the British Museum collection of minerals in 1828 (Smith, 1969 : 249).

Whewell, who, in his report on the recent progress and present state of mineralogy (1833), had given a critical review of the various systems of classification that had been proposed by European mineralogists, while paying tribute to Mohs as well as to Berzelius and Beudant, thoroughly approved of Konig's adoption of the Berzelius system (Whewell, 1833 : 360). He had made an attempt at a system of classification himself in 1828 but probably he was far from satisfied with it for, with unusual modesty, he made no mention of it in his own review of the numerous classifications devised by others. A. J. Berry has given a brief account of it in his oft-quoted review of mineralogy in Cambridge. 'In the long introduction the author states that it is not his intention to propose a new system of classification, but rather to work out a system of nomenclature along the lines adopted by Linnaeus in botany, and to correlate these orders and species with the chemical constitution of the minerals. He used modifications of the names adopted by Mohs . . . and related these to the chemical composition obtained by Berzelius and others' (Berry, 1960 : 7).

A work belonging to a later period which aimed at providing a key to the identification of minerals was published in London in 1843 by E. J. Chapman, a young mineralogist who found previous authors' methods unacceptable. It was entitled *Practical mineralogy, or a compendium of the distinguishing characters of minerals by which the name of any species or variety in the mineral kingdom may be speedily ascertained*. Chapman was then 22 and an engineer; later he lectured on minerals at University College London and became Professor of Mineralogy and Geology at Toronto from 1853 to 1895.

Other books on mineralogy, more concerned with the description of minerals, to some extent with crystallography, and with localities at which the minerals were known to occur, soon became available in England and Scotland. Early and important among these is William Phillips' *Elementary introduction to the knowledge of mineralogy*, first published in 1816. A second edition appeared three years later and a third in 1823. Phillips' work will be referred to again below.

A little later appeared Haidinger's translation of Mohs' *Grund-Riss der Mineralogie*, published in Edinburgh in 1825 and followed, also in Edinburgh in 1834, by Robert Allan's *Manual of mineralogy*. This Robert (1806–1863) was the eldest son of Thomas Allan at whose invitation Haidinger had come to Edinburgh to translate Mohs' work. With his father and Haidinger he had visited the Cornish mines in 1821. He studied crystallography with Haidinger and with him toured the mines and mining academies of Europe, visiting also the volcanoes of Italy and Sicily in 1825–1826. With his father's splendid collection available for study he was well equipped for his task and his *Manual* must have been a very useful text-book. He went on in 1837 to publish a fourth edition of Phillips' *Elementary introduction*. In his own *Manual* he had discussed classification and concluded that until chemical composition was better known the Natural Historical System of Mohs was adequate though confessedly defective. In his edition of Phillips, however, he retained Phillips' own arrangement, contenting himself with the addition of some 150 more minerals and many figures of crystals in the text. By curtailing the descriptions of mere varieties he produced a volume not very much larger than the third edition.

Other text-books of mineralogy emanated from Scotland in the first half of the nineteenth century. Perhaps the most considerable was *Outlines of mineralogy, geology and mineral analysis* in two volumes by Thomas Thomson of Glasgow (see p. 56), published in London in 1836. The work had been ten years in preparation. The *Outlines of mineralogy* (Volume 1, 726 pp.) contains an introductory discussion of the characters of minerals and Mohs' system of classification. Thomson himself opts for a chemical arrangement, classifying minerals in genera under three classes: acid bases, alkaline bases, and neutral bases. Descriptions of the minerals included notes on chemical constituents, and on the simple crystal forms, and there are extensive tables in an appendix. The first of these tables lists for all the minerals: specific gravity, hardness and, where known, the primary crystal form. Two others give lists of minerals in order of increasing specific gravity from scheererite to native iridium, and in order of increasing hardness.

A few years later, in 1849, James Nicol, at that time Professor of Geology at Queen's College, Cork, published in Edinburgh a *Manual of mineralogy*. His *Elements of mineralogy* followed in 1858, when he was Professor of Natural History at Marischal College, Aberdeen.

In England, in that same year of 1858, there appeared Greg & Lettsom's *Manual of the mineralogy of Great Britain and Ireland* the first and only British mineralogy since Sowerby, except for *The mineralogists' directory* by Townshend M. Hall (Hall, 1868) and F. W. Rudler's *Handbook to a collection of the minerals of the British Islands, mostly selected from the Ludlam Collection* . . . (1905).

The teaching of mineralogy in the nineteenth century

Evidence of the growing interest in mineralogy is found in the preface to the second edition of William Phillips' *Elementary introduction to the knowledge of mineralogy* (1819), where he is able to record not only that 'lectures are given at public institutions' in London, but he also lists three persons in the metropolis who give private instruction in crystallography. One of these was Thomas Webster, the curator of the Geological Society's Collection (1812) and draughtsman to the Society, whilst another was Mrs Lowry of Titchfield Street, whose daughter Devalle Lowry wrote a popular book in two volumes entitled *Conversations in mineralogy* (1822). Furthermore, 'models cut in box-wood with great accuracy and beauty by N. J. Larkin, may be had of Bate in The Poultry and Mawe in the Strand, at one guinea each, as well as complete sets of models of all crystals described by Haüy in his *Treatise on Mineralogy* at the price of sixteen pounds the set'. John Mawe, a mineral dealer, had published small books on mineralogy and mining. One of these on *The mineralogy of Derbyshire* (1802) gave a description of mines in the north of England, in Scotland, and in Wales, including Ecton, and Parys mine in Anglesey, and also 'an analysis of Mr Williams's work intitled *The Mineral Kingdom*' (Williams, 1789, 1810).

In London colleges mineralogy was probably not taught apart from geology. University College, founded in 1826, did not establish a Chair in Geology until 1841, although the question had been discussed in 1828. At that time, according to Prestwich, the only nominal instruction in geology and mineralogy was to be had in three lectures by Dr [Edward] Turner at the end of his course on chemistry. John Phillips gave a course of twelve lectures there in 1831 but these were all on geology (Edmonds, 1975). The first professor appointed at the College was Thomas Webster, referred to above and he probably included mineralogy in his course.

We know that E. J. Chapman taught mineralogy in the College for a time before he went to Toronto in 1853 (p. 61) and T. G. Bonney, Professor of Geology from 1877–1905, could hardly have resisted giving some lectures on petrology, of which he was one of the pioneers.

King's College, founded two years later than University College, had Sir Charles Lyell (1831–1834), John Phillips (1834–1840), and D. T. Ansted (1840–1853) as its first three geology professors. Of these Ansted also practised as a consulting geologist and mining engineer, and his successor James Tennant (1853–1869) was a well-known mineralogist and mineral dealer. For a time, after the death of Charles Konig in 1851, he had been curating the Mineral Collection in the British Museum.

This seems the place to record also the work of F. Rutley and F. W. Rudler. The former was a lecturer in the Royal School of Mines in 1882 under J. W. Judd, who had been appointed professor there in 1876. Rudler had been lecturer in Natural Sciences in the University College of Wales, Aberystwyth, from 1876 to 1879 when he returned to his earlier appointment of curator of the old 'Jermyn Street' Museum of Practical Geology. He had made his first catalogue of the collections there in 1864.

Away from the metropolis Durham had a Reader in Mineralogy, J. F. W. Johnston, from 1833 (see p. 57). In Scotland, Robert Jameson, Professor of Natural History in Edinburgh from 1804, inspired great interest by his lectures on mineralogy and geology and continued to do so until 1847 when deteriorating health limited his activities. He died aged 80 in 1854. The Regius Professorship of Geology in Edinburgh was not founded until 1871 and Sir Archibald Geikie was the first occupant of the chair.

In St Andrews, M. Forster Heddle, already an enthusiastic mineralogist, succeeded to the Professorship of Chemistry in 1862. Whilst there he made, and had made, a great number of mineral analyses. He relinquished the Professorship in 1883 but soon returned to St Andrews devoting himself to adding to his collection of minerals, to writing, and to working on his *Mineralogy of Scotland*, which was published in 1901, four years after his death.

Glasgow had appointed Thomas Thomson Professor of Chemistry in 1817 and doubtless he gave lectures on mineralogy and mineral analyses on the lines of his *Outlines of mineralogy, geology, and mineral analysis* published in 1836 (see p. 56).

The important part played by the Royal Dublin Society in promoting the study of mineralogy has been described above (p. 57). Here William Higgins, who had followed Kirwan to Dublin in 1792, became curator of the Leskean Collection of Minerals in 1795 and subsequently Professor of Chemistry and Mineralogy. In 1812 a separate Professorship of Mineralogy was decided on. The post was offered to Robert Jameson who appears to have accepted it, but he was prevented from taking up the post and it was then offered to Charles Louis (Lewis) Giesecke. He was appointed in 1814, and his lectures and teaching of mineralogy became famous (p. 57). On his death in 1833 Dr John Scouler, Professor of Natural History in Glasgow, took his place. Queen's College, Cork, then the Cork Institution, had a lectureship in mineralogy for which we learn one of Jameson's students, James Ogilby, had applied in 1816 (Sweet, 1967, 1974). James Nicol was Professor of Geology there in 1849.

At Trinity College, Dublin, Samuel Haughton had succeeded Thomas Oldham as Professor of Geology and held the post from 1851 to 1881. His work in mineralogy was chiefly concerned with chemical petrology. He was an original member of the Mineralogical Society.

The teaching of mineralogy formed part of the wider instruction in mining which was organized in Cornwall at Truro, Redruth, Penzance, and Camborne at various times from 1838 onwards. A mining school for part-time students was established in Truro in 1838 by Sir Charles Lemon and was carried on for some years at his expense. Additional information on this subject has been provided by Dr L. P. S. Piper, Vice-Principal of the Cornwall Technical College at Redruth, who reviewed the history of technical education in Cornwall, and has recently published 'A short history of the Camborne School of Mines' (Piper, 1975).

In 1859 the Miners' Association of Devon and Cornwall was founded, largely through the initiative of Robert Hunt and the Fox family of Falmouth. Mining classes were arranged in Camborne, Redruth, and Penzance and many distinguished lecturers were engaged. These included Richard Pearce, Robert Hunt, Sir Warrington Smyth, Sir Clement le Neve Foster (1865–1867), and J. H. Collins (1868–1870). The Camborne School of Metalliferous Mining was founded in 1888, partly through the efforts of J. J. Beringer who became its Principal in 1892 and so remained until 1910, when the School was taken over by the County Council of Cornwall. Beringer continued as Vice-Principal until his death in 1915. Others who taught mineralogy in this school in recent years were H. R. Beringer, brother of J. J., E. H. Davison, John Robson, and K. F. G. Hosking.

In Penzance A. K. Barnett was lecturing on mining in 1873, holding his classes in the rooms of the Royal Geological Society of Cornwall. He had been a student under both le Neve Foster and J. H. Collins. In 1890 the Penzance Mining School was opened and it was due to Barnett's enthusiasm that this school survived. In the opinion of Dr Piper, Vice-Principal of Cornwall Technical College, A. K. Barnett was to Penzance what J. J. Beringer was to Camborne (Piper, L. P. S., pers. comm.).

Some reference has already been made to the teaching of mineralogy at Cambridge and Oxford in the early years of the nineteenth century (p. 59). The first professor of the subject at Cambridge, Edward Daniel Clarke, began to give lectures on minerals in 1807 and their success was such that a Chair in Mineralogy was founded in the following year. He published a syllabus of his proposed lectures in the preface to which he gave some idea of their scope and aims. To quote from A. J. Berry's *Sketch of the study of crystallography and mineralogy in Cambridge* (Berry, 1960), his principal object was to 'call the attention of the University to the history of the materials used by architects, sculptors and lapidaries, in the remotest periods, and in modern times; the mineralogy of the ancient poets and historians; and then finally to suggest the means

of pursuing this branch of knowledge without the expense and encumbrance which have usually been its attendants'.

Clarke also published *A methodical distribution of the mineral kingdom* (1806) devised by himself, the divisions of which were, to quote his own words 'as old as the time of Avicenna (979–1037), and which with little variety have been adopted by almost all succeeding writers' (Clarke, 1818).

Clarke died in 1822 when only 53; he was succeeded by J. S. Henslow, naturalist and botanist, who became Professor of Botany in 1825. His place was taken by William Whewell, later (1841) to become a famous Master of Trinity, a brilliant mathematician who had been attracted by the symmetry of crystals and had turned his attention to crystallography. Under Whewell the teaching of mineralogy at Cambridge developed in the crystallographic direction and so continued for very many years under W. H. Miller (1832–1880) and W. J. Lewis (1881–1926).

In Oxford the same thing happened, though at a later date. William Buckland, who had carried on the teaching after John Kidd from 1813, had handed over the duties of Reader in Mineralogy in 1850 to one of his pupils, Nevil Story-Maskelyne, a grandson of Nevil Maskelyne, the Astronomer-Royal. He graduated in mathematics in 1845, but was also actively interested in science, and he had worked for a time in Faraday's laboratory at the Royal Institution in London. He was officially appointed Reader in Mineralogy in 1856 and became the first Professor of Mineralogy in 1861 when the Waynflete Chair was founded. His main interest was the study and teaching of crystallography.

Maskelyne's duties as Professor were not such as to necessitate his residence in Oxford for long periods and thus he was able to accept an appointment as Keeper of Minerals in the British Museum in 1857 when the former Department of Mineralogy and Geology was made into two separate departments. He resigned this Museum appointment in 1880 but he continued as Professor at Oxford until 1895. He numbered among his pupils L. Fletcher, W. J. Lewis, and H. A. Miers (Anon. [Spencer], 1913b).

Thus in Cambridge and in Oxford the teaching of crystallography was well established and it is to the further development of crystallography in Great Britain that one can now turn.

The development of crystallography

Romé de l'Isle and Haüy had established their 'laws' by observing and measuring a great number of crystals and cleavage forms: Romé de l'Isle, for example, had described over four hundred crystal forms. All their measurements had been made with a contact goniometer designed by Carangeot. With well-developed crystals or good cleavage forms it was possible to get tolerably reliable measurements but it was a tedious process and one needed to be quite adept at handling the crystal and the instrument, and the accuracy obtainable was not good. Miers (1902 : 100, fig. 200) illustrates a contact goniometer exactly like Haüy's. It was given by the Duke of Buckingham in 1824 to Buckland, Reader in Mineralogy and Professor of Geology at Oxford. The Duke bought Haüy's collection of minerals in 1822 (Smith 1969 : 247).

One can imagine how slowly crystallography would have developed if the only instrument for the measurement of crystals had been goniometers of the contact type. Fortunately, the situation was saved by the invention by W. H. Wollaston in 1809 of the reflecting goniometer familiar now to every student of mineralogy (Wollaston, 1809). With this instrument very good accuracy can be obtained and very small crystals can be measured. In his report on the state of mineralogy made to the British Association in 1832 William Whewell wrote: 'The invention of the reflecting goniometer by Dr Wollaston, was an invaluable gift to the crystallometer; and every step of our progress makes us more sensible of the importance of this elegant and well-designed instrument' (Whewell, 1833 : 352). Later Whewell wrote: 'Wollaston by the invention of the reflecting goniometer, placed an entirely new degree of accuracy within the reach of the crystallographer'; and further 'In the use of this instrument, no one was more laborious and successful than William Phillips . . . and Mr [H. J.] Brooke, a crystallographer of the same exact and careful school . . .' (Whewell, 1857).

In fact William Phillips, as early as 1814, published an elaborate paper on the different modifications in the crystalline forms of cassiterite based on measurements made with the new goniometer (Phillips, 1814). Two years later he published the first edition of his *Elementary introduction to mineralogy*; a second edition appeared in 1819, and a third in 1823.

In his third edition he was able to include measurements of the interfacial angles of crystals of a great many minerals illustrated by figures 'engraved on wood by W. Hughes', and for most species he endeavoured to give the primary form, usually with a figure. 'The letters on each plane of the larger figures have been so placed according to the system of notation adopted in the *Familiar Introduction* . . . by H. J. Brooke' (see below, p. 65).

In the 'Advertisement' to the third edition he gives his appreciation of the accuracy obtainable with Wollaston's goniometer. 'Experience', he wrote, 'leads to the conclusion that the limit of error is considerably within one degree,—that it rarely exceeds 40 minutes, and that it is frequently confined to a minute or two . . . but where those (the interfacial angles) of the primary form have been obtained from planes produced by cleavage . . . they may be considered as approximating to the truth much more nearly than when taken by means of natural planes.'

H. J. Brooke, the second of the two so favourably mentioned by Whewell as having contributed so many measurements of crystals in the early days of the 'reflective goniometer', was responsible for many papers on various minerals between 1820 and the year of his death, 1857. Many of these deal with crystalline form and include a series of twelve papers 'On the crystalline forms of artificial salts' in Thomson's *Annals of Philosophy* for 1823 and 1824. Two later papers are on crystallization, and on isomorphism (Brooke, 1825, 1831). In the latter he makes some comments as to the degree to which measured interfacial angles bear out the claims made by Mitscherlich for isomorphous groups.

He also published in 1823 *A familiar introduction to crystallography*, dedicated to Wollaston. In this he used a system of letters and subscript figures as indices of crystal forms. He used the capital letters P, M, T, for the *primitive*, or primary forms, and other letters in small type for secondary and other faces. The system may have been suggested to him by the method used by Bournon in his treatise on the crystal forms of calcite and aragonite (see p. 60), wherein he allotted numbers to each of the forms he found.

In his calculations of the laws of decrement producing secondary planes, Brooke showed how this could be done using the formulae of spherical trigonometry which, as Whewell remarked in his 1832 report, 'has in great measure been followed by others' (Whewell, 1833).

Brooke also wrote a treatise on crystallography and an article on mineralogy in the *Encyclopaedia Metropolitana* (1845a, b). In the former he reduced the number of primary forms from the sixteen in his *Familiar introduction* (1823) to six, corresponding to the six crystal systems.

Brooke was co-editor with W. H. Miller of a new edition of Phillips in 1852. Evidently anxious to make it clear that Professor Miller had contributed the major share to the arrangement and re-writing of the book, Brooke wrote a postscript to the preface in which he states that his share in the work consisted of 'such information relating to the minerals described as a long acquaintance with them enabled me to afford, and in having supplied such specimens and crystals as it appeared desirable again to examine and measure'. Brooke's collection was presented to the University of Cambridge in 1857 by his son. It was kept in its own cabinet in accordance with his son's wishes. Also in the Cambridge collection are some of W. H. Wollaston's mineral specimens. They formed part of Henry Warburton's collection presented by H. W. Elphinstone in 1858.

William Whewell who, as mentioned above (p. 64), succeeded Henslow as Professor of Mineralogy at Cambridge, wrote all his important papers on crystallography before his formal appointment to the professorship. In 1822 he read a short paper explaining the interpenetrant twin cubic crystals of fluorite, in the course of which he offered some pertinent criticism of Haiiy's theory of integrant molecules (Whewell, 1822). His three next papers, 1825–1827, all deal with a system of notation for crystal faces and with calculations of interfacial angles.

In the *Philosophical Transactions* for 1825 he gave 'A general method of calculating the angles made by any planes of crystals, and the laws according to which they are formed' (Whewell, 1825a). An abstract of the paper was published in the *Edinburgh Journal of Science* and in this Whewell added 'formulae for calculating the angles made by any secondary faces of a crystal

when the law of its derivation from the primary is known' (Whewell, 1825b). Whewell, starting from Häüy's theory and his method of developing secondary faces by decrements of the 'integrant molecules' parallel to two or more of the edges of the primary form, set out to express such secondary planes by algebraic equations. Taking as origin the angle of a primary form and the three edges of, for example, a rhomboid as axes XYZ he showed that 'the equation of a plane arising from the decrements will be such that the coefficients of the three co-ordinates in it (when reduced to its simplest form) will be the reciprocals of the numbers of the molecules subtracted on the edges to which they correspond; or put in another way: if the three edges of a rhomboid are taken as axes, X, Y, Z, then any face P Q R making intercepts $\frac{x}{h}, \frac{y}{k}, \frac{z}{l}$ has for its indices $\frac{1}{h}, \frac{1}{k}, \frac{1}{l}$, or (*p; q; r*), written with semi-colons between them and in parentheses'.

There were two more papers read before the Cambridge Philosophical Society (Whewell, 1827a, b). In these Whewell sought to explain and to improve upon the system of notation proposed by Mohs (1825) and by Naumann (1826), and he proposed a modification of Mohs' notation doing away with the + sign which had encumbered it. He gave a 'specimen of the use of notation in the analysis of crystalline forms taking as an example crystals belonging to the rhombohedral system' (Whewell, 1827c). He also, very briefly, explained his method in his *History of the inductive sciences* (1857: 184-185).

Whewell resigned the professorship in 1832. In the same year he presented a report to the British Association on 'The recent progress and present state of mineralogy', which was published in 1833. In this he was very critical of British contributions to mineralogy but he knew that he had in W. H. Miller a successor for the Chair of Mineralogy who would establish in Cambridge the crystallography he had begun to develop.

William Hallows (or Hallowes) Miller, who succeeded Whewell, was only seven years his junior. Like Whewell he was a mathematician; he had been fifth Wrangler in 1826. He wrote books on hydrostatics and on the differential calculus and was best known for his extremely accurate work in the preparation of new standards for the pound weight.

Miller had also written papers on the position of the axes of optical elasticity in crystals belonging to the oblique-prismatic system (Miller, 1835), and on the unequal expansion of minerals in different directions by heat (Miller, 1837). His first paper relating to crystallography on the forms of ammonium bicarbonate was published in 1829, the year after Whewell became professor. After this he wrote only some 24 papers on crystallography, some of which are mentioned below, but his very important early work was *A treatise on crystallography* completed in 1838 and published in 1839. In this he announced his method of describing the position of any face with reference to three axes parallel to possible edges of the crystal by three numerals, rational whole numbers, which are, in the words of Nevil Story-Maskelyne, 'the denominations of three fractions with unity for their numerator and in the ratio of the multiples of the parameters' (Maskelyne, 1880).

Miller explained in the preface to his *Treatise* that he took the idea for the Millerian indices, as they are always known, from Whewell's paper (1825a), referred to above (p. 65) and also that he owed to Neumann (1823) the method by which crystal faces are indicated by the points in which radii drawn normal to the faces meet the surface of a circumscribing sphere. In this *Treatise*, making use of the methods of spherical trigonometry, he developed a great many formulae for the calculation of interfacial angles, face symbols and zone symbols, all adapted for the use of logarithms.

Miller's next great work was the 1852 edition of Phillips' *Mineralogy* which he wrote with Brooke as described above (p. 65). The full title of the book, *An elementary introduction to mineralogy*, was now somewhat misleading. It was a new book and far from 'elementary', it contained a vast number of results of crystal measurements by Miller and Brooke. In it Miller further developed his system of indices and methods of calculation and established the fundamental formulae in the general case and went on to demonstrate the simplified formulae applicable to crystals in his six systems of symmetry.

The descriptive mineralogical parts of the book recorded the principal localities at which each mineral had been found, provided some chemical analyses, gave tables of measured angles,

recorded the fundamental angles (but not parameters), and gave lists of forms identified, illustrated by figures and by stereographic projections. The book with index ran to 697 pages with 647 figures. Story-Maskelyne described it as 'a monument to Miller's name. It will not be superseded and will always be referred to' (Maskelyne, 1880).

After the publication of this book Miller wrote several important papers on crystallography. One was his first statement 'On the anharmonic ratio of radii normal to four faces of a crystal in one zone' (Miller, 1857a). A second paper was a development of this: 'An improved method of finding the position of any face in crystals belonging to the anorthic system'. It uses 'the anharmonic ratio of the axes of four *zones* having a face in common' (Miller, 1858).

These and two later papers on the gnomonic and stereographic projections, published in his Crystallographic Notices in the *Philosophical Magazine* between 1857 and 1860, were incorporated in Miller's last book, *A tract on crystallography*, published in 1863. This, in Miller's own words, 'contains an investigation of the general geometrical properties of the systems of planes by which crystals are bounded, and of the formulae for calculating their dihedral angles, indices, and elements, given without demonstration in the last, 1852, edition of Phillips' *Mineralogy*; or of equivalent expressions in more convenient shape'. It was in fact a supplement to 'Brooke & Miller'. The *Tract* also included two chapters on geometrical and analytical investigations of a system of planes suggested to Miller by a paper by C. Q. Sella in 1856 on which Miller had already published a short paper in 1857 (Miller, 1857b).

Miller died in Cambridge in 1880 at the age of eighty. He had held the professorship for 48 years. There were many tributes to the man and to his work; several of these have been referred to, and quoted from, by A. J. Berry (1960) in his paper to which I have so often referred and from which I have derived so much information. Notable among these is one by T. G. Bonney in the *St John's College Magazine* (Bonney, 1880), and one in *Nature* by Story-Maskelyne who wrote: 'He placed the keystone in the arch of the science of crystallography. Future development of that science will follow on the lines laid down by Miller' (Maskelyne, 1880), a prophecy which has been abundantly fulfilled.

At Oxford, Maskelyne had been appointed Professor of Mineralogy in 1861 (see p. 64). He published little on crystallography at this time but preferred to concentrate on his teaching. However, he had in hand a book, parts of which formed the basis of his lectures on crystallography in the 1860s and, as Maskelyne states in his preface, was indeed in print. Unfortunately, it was not published until 1895 and then only as a result of persuasion and assistance from Lazarus Fletcher and Henry Miers, both pupils of his and colleagues at the British Museum (Natural History) (Maskelyne, 1895). Even as late as 1895 it seems to have been the first text-book in English to deal in detail with the subject since Miller. The chapters on crystal symmetry received high praise from A. E. H. Tutton in his review of the book (Tutton, 1895), but he criticized Maskelyne for setting his axes with OX to the right of the origin and OY to the front instead of making OX the front and OY to the right, which was the orientation used by P. Groth in, for instance, his *Physikalische Krystallographie* (1876), which continental crystallographers followed, and which Lewis adopted in his *Treatise* in 1899. However, it is only fair to Maskelyne to remark that when he actually wrote parts of his book and had had it set up in type he was following the orientation used by Miller whose last book, the *Tract*, was published probably about the time Maskelyne was writing.

Tutton describes as almost prophetic a passage which Maskelyne wrote when considering the ultimate significance of symmetry (*op. cit.*, p. 171). Tutton quotes from the passage the most important sentence, but it seems worthwhile to reproduce the whole passage here: '... the whole treatment of crystallographic symmetry on the assumption of planes and axes of symmetry, actual or potential, represents a geometrical abstraction; an abstraction that needs for its development and due expansion a complete science of position applied to the molecular mass-centres, competent to embrace not merely the relative distribution *inter se* – the *intermolecular* distribution – of the chemical molecules constituting the crystallised substance, but also the *intramolecular* arrangement of the atoms, or molecules of secondary order, whereof the molecules of the substance are themselves composed. Then the true significance of the ideal planes and axes of symmetry will be understood; and they will assuredly retain a place in the explanation of

crystalline symmetry, since they rise into recognition directly from the fundamental principle of rationality of indices and are controlled by its consequences.'

The classification of crystal forms into the six (or seven) systems of symmetry now in use by geometrical crystallographers was developed from the early ideas of Romé de l'Isle and Haüy mainly by Mohs and Weiss and later by Naumann in Germany and Austria, and by Michel Lévy in France. We cannot claim any considerable contribution to this classification by British mineralogists in these early days.

At first Mohs had grouped all crystal forms in four systems: Cubic (or Tesseral of Whewell), Pyramidal (Tetragonal), Rhombohedral, and Prismatic (Rhombic), considering as hemihedral those forms with half the number of faces of the holohedral forms. These he later brought into two more Systems, Monoclinic and Triclinic. These six systems were those adopted in 'Brooke & Miller' (1852) and only slightly modified by later authors. W. J. Lewis in Cambridge and Alfred J. Moses in Columbia University (both writing in 1899) divided the Rhombohedral System into two, Rhombohedral and Hexagonal; but E. S. Dana (1892) had adhered to the single system naming it Hexagonal, and H. A. Miers (1902) had the same six systems but preferred the name *Cubic* to the *Isometric* adopted by American authors.

After this short digression on the names of the crystal systems one must return to the early years of the nineteenth century to record something of the work of Sir David Brewster, whose discoveries of the optical properties of crystals established the correlation of these properties with the symmetry of the crystals. His work on these phenomena commenced about 1815 and some of the most important results were brought together in a paper read before the Royal Society in January 1818 (Brewster, 1818). In this paper he showed that whereas minerals and salts crystallizing in the Hexagonal and Tetragonal systems had a single optic axis parallel in direction to the principal axis of the crystal, those crystallizing in the Prismatic, Oblique, and Anorthic Systems possessed two optic axes the positions of which he described.

Without any of the conosopes or polarizing microscopes later available, but using plates of glass as polarizer and analyser, and a candle-flame or the sky as a light source, he described most of the phenomena now familiar in our text-books on crystal optics. He observed and described the coloured rings and the black cross shown by uniaxial crystals, the lemniscates and brushes of biaxial ones; the properties displayed by sector twins of amethyst, aragonite, and analcime; and he wrote on the value of all this in the determination of mineral species: an almost endless list of observations and all new (Brewster, 1834). All these and more were briefly recorded by Whewell in his report to the British Association already referred to (Whewell, 1833), and in the same report he summarized Sir John Herschel's demonstration of the dispersion of the optic axes, the rotatory polarization of light, and the correlation of the direction of rotation of the plane of polarization with right- and left-handedness in crystals (Whewell, 1833, 1857).

These observations of Brewster's, and of Herschel's must have had an effect on mineralogists comparable to that of von Laue's demonstration of the diffraction of X-rays by the crystal structure of zinc-blende in 1912. Herschel himself wrote of Brewster: 'The discovery of crystals which possess two axes of double refraction, . . ., is perhaps the greatest step which has been made in physical optics since the discovery of double refraction itself by Bartholinus. . . . It has opened new views on the structure of crystals, and will in all probability be the means of leading us to a more intimate knowledge of the nature and laws of those forces by which the ultimate particles of matter act on light and on each other' (Herschel, 1822 : 21).

To return now to the work of Nevil Story-Maskelyne, Professor of Mineralogy at Oxford; he had been appointed also Keeper of Minerals in the British Museum in 1857 (p. 64) but still carried on his teaching. Since the death of Charles König in 1851 there had been no one on the staff of the old Department of Natural History in the British Museum interested in minerals. With the appointment of Maskelyne the Department began to play a more important part in the progress of mineralogy and crystallography in London.

In spite of miserably poor conditions for testing minerals or measuring crystals Maskelyne succeeded in getting some reliable work done. He had to assist him with the Collection only Thomas Davies, then a complete novice of 21 but who, under Maskelyne, became a very competent mineralogist. Davies was appointed in 1858. In 1862 Maskelyne invited Viktor von Lang

(later Professor of Physics in the University of Vienna) to join him as an 'Assistant'. Together they produced numerous 'Mineralogical Notes' in the *Philosophical Magazine* for 1863 and 1864. It was not until 1867 that Walter Flight joined the Department as a chemist and a laboratory was set up at no. 46 Great Russell Street because neither gas lights nor burners were allowed in the rooms of the British Museum.

In the *Philosophical Magazine* von Lang's papers were on the crystal forms of numerous minerals, while Maskelyne contributed one on connellite and one on columbite, all giving angular measurements and all well illustrated by crystal drawings. In his paper on connellite Maskelyne describes how he succeeded in measuring extremely small crystals by attaching to the Wollaston goniometer a small plano-convex lens in front of a small telescope 'which converts that telescope into a sort of microscope of low power', so introducing a device later used in horizontal goniometers by Fuess and others.

Maskelyne's other papers in this series of 'Notes' gave a general account of stony meteorites and descriptions of fifteen stones in the British Museum meteorite collection. He followed these with a paper read before the Royal Society in 1870 on the mineral constituents of meteorites. In connection with his work on meteorites, as early as 1861, he had a binocular microscope fitted with a polarizer and analyser and a rotating stage to assist him in the identification of minerals in thin sections of stony meteorites, the preparation of which he describes.

Maskelyne reclassified the great mineral collection following the crystallo-chemical system of Gustav Rose and replacing the system of Berzelius adopted by Konig in 1828. The rearrangement of the collection was made with the move of the Natural History Departments to the new Museum at South Kensington in mind but the actual move was not completed in Maskelyne's time. He had to give up his appointment at the Museum on the death of his father in 1879. In the last few years he had two of his old Oxford pupils as Assistants: W. J. Lewis, from 1875 to 1877, and Lazarus Fletcher, who was appointed in 1878 and succeeded to the Keepership in 1880 on Maskelyne's retirement.

This completes my account of early mineralogy in Great Britain, covering a period of 200 years and bringing us to the foundation of the Mineralogical Society of Great Britain and Ireland over a hundred years ago (Smith, 1976).

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